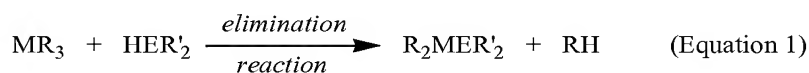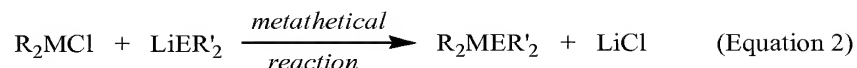## Remarks

In view of the above amendments and the following remarks, reconsideration of the outstanding office action is respectfully requested.

There is considerable interest in processes for the preparation of semiconductor nanocrystals, the applications for which include, for example, optical communications, photonic chips, photovoltaic devices, and biolabels for bioimaging. Traditional preparative routes to III-V semiconductor nanocrystals require the use of coordination solvents such as trioctylphosphine oxide ("TOPO") or dodecylamine ("DA") and generally require long reaction times at high temperatures (i.e., 3-6 days at ~ 300-400°C). Decomposition products resulting from these methods have been shown to possess optical properties which have the potential to interfere with the optical properties of the desired III-V nanocrystals. Moreover, the III-V semiconductor nanocrystals prepared by these methods are generally polydispersed (1-20 nm) and the results are somewhat erratic or irreproducible. An added disadvantage is that when any of the commonly utilized surfactants are exposed to high temperatures (>100°C), their optical properties also have the potential to mask or obscure the optical properties of the desired nanocrystals.

Other existing preparation technologies include Molecular Beam Epitaxi (MBE) and Chemical Vapor Deposition (CVD). However, although both of these methods are excellent techniques for the preparation of thin film or bulk III-V semiconductor materials, neither technique is capable of producing monodispersed III-V semiconductor nanocrystals and neither offers control or exchange of the surface capping material which would allow incorporation of the semiconductor nanocrystals into desired host matrices.

Compounds of the type $M(ER_x)_3$ (M = Group III metal; E = Group V or Group VI element; R = organic group; x = 1 if E is Group VI element, and x = 2 if E is Group V element) may be used as precursors for the synthesis of III-V semiconductor nanocrystals. The best precursors should be soluble in non-coordinating organic solvents, that have high boiling and high decomposition temperatures, and which can be prepared in very high purity. The typical synthetic routes to these types of compounds are either hydrocarbon elimination reactions (Equation 1) or metathesis reactions (Equation 2).

$$MR_3 \ + \ HER'_2 \ \xrightarrow{\substack{elimination \\ reaction}} \ R_2MER'_2 \ + \ RH \qquad \text{(Equation 1)}$$

$$R_2MCl + LiER'_2 \xrightarrow[\textit{reaction}]{\textit{metathetical}} R_2MER'_2 + LiCl \qquad \text{(Equation 2)}$$

The major source of impurities in precursors prepared by the elimination reactions originates with the high temperatures needed to initiate the elimination reaction between the pure starting materials, the organo group III compound, and the Group V compound. Elimination reactions for gallium-nitrogen systems require 100-130°C, whereas gallium-phosphorus compounds need 110-150°C. For example, the compounds $[Me_2GaNH_2]_3$, $[Me_2GaN(H)(Me)]_3$, $[Me_2GaNMe_2]$, $[Me_2GaN(H)(t-Bu)]_2$, and $[Me_2GaNPh_2]_2$ have been prepared from the neat reagents, $GaMe_3$, and the corresponding amine, at 90, 125, 125, 110, and 120°C, respectively, whereas $[Me_2GaN(H)Ph]_2$, $[Me_2GaN(H)Ad]_2$ (Ad = 1-adamantyl), and $[Me_2GaN(H)Dipp]_2$ (Dipp = 2,6-i-$Pr_2C_6H_3$) have been formed from $GaMe_3$ and the corresponding amine in refluxing toluene (bp 110°C). The diethylgallium-nitrogen, diethylgallium-thiol and diethylgallium-phosphorus compounds $[Et_2GaS(SiPh_3)]_2$, $[Et_2GaPEt_2]_2$ and $[Et_2GaN(C_2H_4)]_2$ have been prepared directly from $GaEt_3$ and $HS(SiPh_3)$, $HPEt_2$, and $HN(C_2H_4)$, respectively, neat at 70, 100-150, and 110-150°C, respectively. The gallium-phosphorus compounds, $[Me_2GaPMe_2]_3$, $[Me_2GaPEt_2]_2$, and $[Me_2GaPPh_2]_2$, require heating the corresponding neat reagents to 150, 160, and 110°C, respectively. It is noteworthy that when $GaMe_3$ and H_2NMes (Mes = 2,4,6-MeC_6H_2) are combined in refluxing toluene and then heated at 190°C, products indicative of orthometalation reaction have been observed. Metathesis reactions on the other hand, require more reagents with multistep synthesis and typically require the use of ether solvents. Since each new reagent or solvent introduces the possibility of impurities, the simplest reaction should give the purest product.

The reaction between $Me_2Ga(C_5H_5)$ and a primary and/or secondary amine or a phosphine (Equation 3) occurs at or below room temperature and provides a convenient, low-temperature route to gallium-nitrogen and gallium-phosphorus compounds of high purity.

$$Me_2Ga(C_5H_5) + HERR' \longrightarrow 1/n[Me_2GaERR']_n + C_5H_6 \qquad \text{(Equation 3)}$$

The compounds $[Me_2GaNH_2]_3$, $[Me_2GaN(H)(Me)]_3$, $[Me_2GaN(H)(t-Bu)]_2$, $[Me_2GaN(H)(C_6H_{11})]_2$, $[Me_2GaNEt_2]_2$, $[Me_2GaN(Me)(C_6H_{11}]_2$, $[Me_2GaN(Me)(Ph)]_2$, $[Me_2GaN(Et)(Ph)]_2$, $[Me_2GaP(C_6H_{11})_2]_2$, $[Me_2GaP(Me)(Ph)]_3$, and $[Me_2GaPPh_2]_2$ have all been prepared at room temperature or below, displaying the ease of cyclopentadiene

elimination over methane elimination in gallium organometallic complexes. The reactions of $Et_2Ga(C_5H_5)$ with $HNEt_2$, $HN(H)Me$, $HN(H)(t\text{-}Bu)$, $HP(i\text{-}Pr)_2$, $HP(t\text{-}Bu)_2$ and $HS(SiPh_3)$ in benzene or pentane provide convenient room temperature routes to the preparation of $[Et_2GaNEt_2]_2$, $[Et_2GaN(H)Me]_2$, $[Et_2GaN(H)(t\text{-}Bu)]_2$, $[Et_2GaP(i\text{-}Pr)_2]_2$, $[Et_2GaP(t\text{-}Bu)_2]_2$, and $[Et_2GaS(SiPh_3)]_2$ through cyclopentadiene elimination over ethane elimination. The compound $[(Me_3CCH_2)_2GaPEt_2]_2$ has been prepared readily at room temperature by combining $Ga(CH_2CMe_3)_3$, $Ga(C_5H_5)_3$, and $HPEt_2$ in a 2:1:3 mol ratio, respectively, in pentane. This displays the ease of elimination of cyclopentadiene over neopentane, as upon dissolution of $Ga(CH_2CMe_3)_3$, $Ga(C_5H_5)_3$ in a 2:1 ratio, the major species present in solution due to ligand redistribution is $(Me_3CCH_2)_2Ga(C_5H_5)$ which reacts, in turn, with $HPEt_2$ to form the resultant product with no side products or by-products that would come from neopentane elimination. Thus, for organometallic gallium complexes, cyclopentadiene elimination occurs in preference to methane, ethane, and neopentane elimination pathways.

It has recently been discovered that similar cyclopentadiene reactions occurr readily with indium complexes (Equation 4).

$$R_2In(C_5H_5) \ + \ HER'R'' \longrightarrow 1/n[R_2InER'R'']_n \ + \ C_5H_6 \qquad \text{(Equation 4)}$$
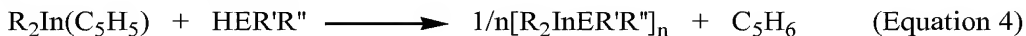
The compounds with the simplest formula $Me_2InO(t\text{-}Bu)$, $Me_2In(acac)$ (acac = acetylacetonate), Me_2InPPh_2, $Me_2InS(SiPh_3)$, $(Me_3CCH_2)_2InO(t\text{-}Bu)$, $(Me_3CCH_2)_2In(acac)$, $(Me_3CCH_2)_2InPPh_2$, $(Me_3CCH_2)_2InS(SiPh_3)$, and $(C_5H_5)_2InO(t\text{-}Bu)$ have been prepared at room temperature or below through cyclopentadiene elimination. Neither methane nor neopentane elimination reactions were observed, and this chemistry demonstrates that cyclopentadiene elimination occurs readily for organoindium complexes.

Traditional preparative routes to II-VI semiconductor nanocrystals require the use of either a coordinating solvent (phosphorus, nitrogen or oxygen based) or a surfactant (phosphorus, nitrogen or oxygen based) and/or a mixture of coordinating solvent and surfactant. Also, these traditional preparative routes generally require long reaction times at high temperatures with most of these approaches utilizing very dangerous and reactive metal precursors (i.e., $CdMe_2$ and $ZnEt_2$). Traditional methods of preparing shell materials also require the utilization of coordinating solvents (such as those solvents listed above) and the preparation of elaborate mixtures of metal precursors.

Moreover, current technologies for III-V semiconductor nanocrystals synthesis are dedicated strictly to using commercially available precursors. The most common precursors are the $M^{III}(halides)_3$. When utilizing these precursors, the resultant semiconductor nanocrystals have the propensity to have halide impurities. These impurities hinder the desired electronic or optical properties of the nanocrystals.

The present invention is directed at overcoming these and other deficiencies in the art.

The rejection of claims 1-36 under 35 U.S.C. § 112 (2nd para.) for indefiniteness is respectfully traversed in view of the above amendments.

The rejection of claims 1, 2, 5, and 6 under 35 U.S.C. § 102(b) as anticipated by U.S. Patent No. 5,505,928 to Alivisatos et al. ("Alivisatos") is respectfully traversed in view of the above amendments and the following remarks.

Alivisatos discloses nanometer-scale crystals of III-V semiconductors and a process for preparing such nanocrystals by reacting a group III metal source with a group V anion source in a liquid phase at elevated temperature in the presence of a crystallite growth terminator, such as pyridine or quinoline. Alivisatos teaches that the reaction medium employed plays a big part in the III-V crystallite form ultimately obtained and that, if a crystal growth terminator such as a nitrogen- or phosphorus-containing polar organic solvent is present in place of the pure nonpolar hydrocarbon of the art, one can obtain III-V crystallites which are sized in the range 30-50 Å and which are relatively monodisperse and redissolvable (column 2, lines 3-12).

However, while Alivisatos may disclose a process for producing III-V nanocrystals by reacting a group III metal with a group V compound, it does not in any way teach or suggest a process for producing III-V nanocrystals by reacting such compounds <u>in the absence of any surfactant, ligand, or coordinating solvent</u> as set forth in the amended claims of the present application. More specifically, Alivisatos does not teach or suggest a "process for producing III-V or II-VI nanocrystals comprising…reacting a compound of formula (I) with a compound of formula (II)…<u>in the absence of any surfactant, ligand, or coordinating solvent</u>…under conditions effective to produce III-V or II-VI nanocrystals (emphasis added)" as required by amended claim 1 (as well as dependent claims 2, 5, and 6) of the present application. Support for the amendments to the claims is found on page 6, lines 17-18, page 6, line 31 – page 7, line 2, page 7, lines 12-15, and page 12, lines 5-8 of the

present application. Thus, the method of the present invention involves reacting a group III metal compound with a group V compound <u>in the absence of any surfactant, ligand, or coordinating solvent</u>. In contrast, the method, as disclosed in Alivisatos, *requires* the presence of a "crystallite growth terminator", i.e., a coordinating solvent. (See column 3, lines 32-34 of Alivisatos stating that "[a] distinguishing feature of the preparation process is that it is carried out in a liquid reaction phase which includes at least one of these crystallite growth terminators."). Thus, the rejection based on Alivisatos is improper and should be withdrawn.

The rejection of claims 9, 11, 15, 16, 22, 23, 25, and 29 under 35 U.S.C. § 102(b) as anticipated by Haubold et al., "Strongly Luminescent InP/ZnS Core-Shell Nanoparticles," *Chem. Phys. Chem.* 5:331-334 (2001) ("Haubold") is respectfully traversed in view of the above amendments and the following remarks.

Haubold discloses ZnS-passivated InP nanoparticles prepared in trioctyl phosphine (TOP) using organometallic precursors, where a strong enhancement of the photoluminescence quantum yield was observed in the particles. Haubold, on page 334, describes that ZnS-coated InP nanocrystals were synthesized in TOP by the dehalosylilation reaction between tristrimethylsilylphosphide ((TMS)$_3$P) and InCl$_3$, followed by quantitative precipitation and washing of the nanocrystals with methanol. After washing, the InP clusters were redissolved in toluene. TOP was then added and the toluene was removed by distillation. To this stock solution, diethyl zinc (Et$_2$Zn) and bistrimethylsilylsulfide ((TMS)$_2$S) were added and the resulting reaction mixture was injected into hot TOP. After heating and cooling, the nanoparticles were precipitated and separated.

While Haubold may disclose a process for preparing InP/ZnS core-shell nanoparticles, it does not in any way teach or suggest a process for producing nanocrystals having multiple layers of III-V material by reacting compounds <u>in the absence of any surfactant, ligand, or coordinating solvent</u> as set forth in the amended claims of the present application. More specifically, Haubold does not teach or suggest a "process for producing nanocrystals having multiple layers of III-V or II-VI material comprising…reacting a compound of formula (I) with a compound of formula (II)…<u>in the absence of any surfactant, ligand, or coordinating solvent</u>…under conditions effective to produce nanocrystals having multiple layers of III-V or II-VI material (emphasis added)" as required by amended claim 9 (as well as dependent claims 11, 15, 16, and 22) of the present application. Nor does

Haubold teach or suggest a "process for producing nanocrystals having multiple layers of III-V or II-VI material comprising…reacting the seed III-V or II-VI nanocrystals with a source of a Group III metal and a Group V element, or with a source of a Group II metal and a Group VI element <u>in the absence of any surfactant, ligand, or coordinating solvent</u>, under conditions effective to produce nanocrystals having multiple layers of III-V or II-VI material (emphasis added)" as required by amended claim 23 (as well as dependent claims 25 and 29) of the present application. Support for the amendments to the claims is found on page 6, lines 14-18, page 6, line 31 – page 7, line 2, page 7, lines 12-15, and page 12, lines 5-8 of the present application. Thus, the method of the present invention involves reacting compounds <u>in the absence of any surfactant, ligand, or coordinating solvent</u>, whereas the method, as disclosed in Haubold, *requires* the presence of TOP, i.e., a coordinating solvent. Thus, the rejection based on Haubold is improper and should be withdrawn.

In view of all of the foregoing, applicants submit that this case is in condition for allowance and such allowance is earnestly solicited.

Respectfully submitted,

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